COMPARISON OF HIGH VOLTAGE THERMAL CONVERTER SCALING TO A BINARY INDUCTIVE VOLTAGE DIVIDER

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Introduction

High-voltage thermal converters (HVTCs) are used as standards of ac-dc difference and for the measurement and calibration of ac voltage up to 1000 V and 100 kHz [1]. Their multiplying resistors can be compensated to yield small ac-dc differences by using adjustable internal shields; however, the ac-dc differences of HVTCs may vary as functions of warm-up time, applied frequency, and applied voltage. Voltage coefficients between 100 V and 1000 V can be quite significant compared to calibration uncertainties, and can be major sources of error in the buildup process used to characterize the HVTCs. Formal and informal international intercomparisons of HVTCs have revealed variations among the participating laboratories [2]. The present work was undertaken to compare the scaling accuracy of HVTCs to the completely independent principle of a binary inductive voltage divider [3].

Binary Inductive Voltage Divider Construction

The BIVD consists of 240 turns of twisted-pair wire connected to form a center tap. This winding technique provides good symmetry and a well-defined center tap. There are two layers of windings with an intermediate layer of a glass tape to provide a greater distance between turns and thus reduce the capacitance of the transformer. The transformer is enclosed in a shielded box with type-874 connectors. The BIVD is designed to operate at 1000 V up to 50 kHz and present a minimal load to a voltage supply.

Binary Inductive Voltage Divider Calibration

The accuracy of the center tap of the BIVD was tested in a bridge configuration against a decade inductive voltage divider set to the ratio 0.5. Since the BIVD is used in TVC measurements with one side of the input grounded, the bridge voltage source was grounded and an isolation transformer was used to allow the detector to be grounded as well. The test was performed by interchanging the input leads on the dividers. The test results are summarized in Table 1. The errors in the BIVD are very small compared to the uncertainties of the HVTC buildup process.

Frequency (kHz)	Voltage 100 V	Voltage 50 V
1	0.1	1
10	0.1	0.1
20	0.6	0.5

Table 1. Center-tap error of the BIVD as a function of the applied voltage and frequency (parts in 10^6). The measurement uncertainty is estimated to be less than 0.5 parts in 10^6.

HVTC to BIVD Comparison System

The system compares the ac-dc differences of two HVTC ranges to the ratio of a BIVD. The comparison requires the knowledge of the BIVD ratio accuracy and the ratio of two high-voltage dc calibrators. The two HVTCs measure the voltages of two high-voltage ac calibrators in terms of the two dc calibrators. The ratio of the two ac calibrators is also determined in terms of the ratio of the BIVD by the use of two high-precision digital voltmeters (DVMs) used only as transfer instruments. The calibration of the DVMs is not required for the measurement

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process which relies only on the linearity of the DVMs over a limited range of voltage.

A schematic of the system is shown in Fig. 1. The two HVTCs are connected simultaneously, in a timed sequence, to the ac and dc calibrators through relays R_1 and R_2. The HVTC outputs are monitored by the digital nanovoltmeters (nVM_H and nVM_L). This procedure determines the ratio of AC calibrators in terms of the ratio of the DC calibrators and the ac-dc differences (δ_H and δ_L) of the two HVTCs. When R_1 and R_2 are in their open positions, the DVMs (DVM_H and DVM_L) are connected to the BIVD through R_3 and R_4. When R_1 and R_2 are in their closed positions, the DVMs are connected to AC_H and AC_L. This procedure determines the ratio of AC_H and AC_L in terms of the BIVD center tap ratio.

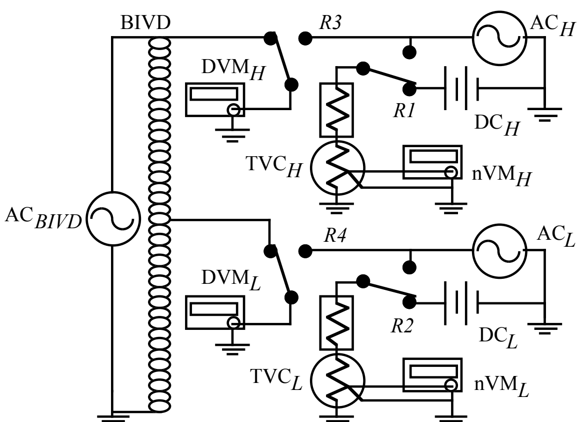

Figure 1. Schematic of the HVTC-BIVD measurement system. Subscripts indicate higher voltage (*H*) and lower voltage (*L*) sections of the system. Relays are shown in the open positions.

To begin the measurement sequence, dc voltage is applied to the HVTCs and AC_{BIVD} is applied to the BIVD. After the HVTCs have stabilized, the ac and dc calibrators (AC_H, DC_H, AC_L, and DC_L) are brought into nominal balance according to the HVTC output. The complete measurement sequence is as follows:

1) the DVMs and the nVMs are read with dc plus applied,
2) the four relays are closed in numerical order,
3) after the system has settled, the DVMs and the nVMs are read with ac applied,
4) the four relays are opened in reverse numerical order,
5) after the system has settled, the DVMs and the nVMs are read with dc minus applied.

The measurement sequence is then repeated.

Neglecting small second-order quantities, the relationship between the ac-dc differences of the higher-voltage converter and the lower voltage converter, δ_H and δ_L respectively, is:

$$\delta_H - \delta_L = \Delta ratio_{ac} - \Delta ratio_{dc} - \delta_H^m + \delta_L^m \qquad (1$$

Where :

δ_H is the ac-dc difference of TVC_H,

δ_L is the ac-dc difference of TVC_L,

$\frac{AC_H}{AC_L} = 2(1+\Delta ratio_{ac})$, $\Delta ratio_{ac}$ is the departure from nominal ratio, determined from the BIVD ratio,

$\frac{DC_H}{DC_L} = 2(1+\Delta ratio_{dc})$,

$\delta_H^m = \frac{E_a - E_d}{nE_d}$ is the measured result from TVC_H with E_a and E_d the TVC output emfs for ac and dc applied and n the TVC square law characteristic, and

δ_L^m is the measured result from TVC_L.

Because this process is intended to confirm a voltage buildup method which goes from lower to higher voltages, the above equations are based on 2:1 relations instead of 0.5:1, as is conventional with inductive dividers.

Results

Preliminary comparisons were made with 200 V applied at 1 kHz. The determination of (δ_H - δ_L) from the BIVD system agrees with the conventional HVTC buildup process to within $(1 \pm 3) \times 10^{-6}$.

Future Plans

The AC_{BIVD} power supply in the present system limits measurements to 200 V at 1 kHz. This instrument is being replaced to permit comparisons up to 1000 V and at least 50 kHz.

References

[1] D.-X. Huang, T.E. Lipe, J.R. Kinard, and C.B. Childers, "AC-DC Difference Characteristics of High-Voltage Thermal Converters," IEEE Trans. Instrum. Meas., Vol. 44, No. 2, pp. 387-390, Apr. 1995.

[2] J.P.M. de Vreede, "CCE Intercomparison of ac-dc Transfer Standards," IEEE Trans. Instrum. Meas., vol. IM-42, pp. 99-108, Apr. 1993.

[3] S. Avramov-Zamurovic, G. N. Stenbakken, A. D. Koffman, and N. M. Oldham, "Binary Versus Decade Inductive Voltage Divider Comparison and Error Decomposition," IEEE Trans. Instrum. Meas., Vol. 44, No. 4, pp. 904-908, Aug. 1995.